# CLIMATE CHANGE

## *scientific certainties and uncertainties*

Climate change is perhaps the most pressing and urgent environmental issue on the world's agenda. In 1995 the UN Intergovernmental Panel on Climate Change (IPCC) concluded that "the balance of evidence suggests a discernible human influence on global climate".

The earth's systems of air, water and land have always been dynamic. Studies of ancient climates show that there have been alternating periods of global warmth and global chill at various times. Sometimes the transitions from one state to another have been abrupt, at other times the rate of change has been slow, but in all cases change has been driven by natural processes.

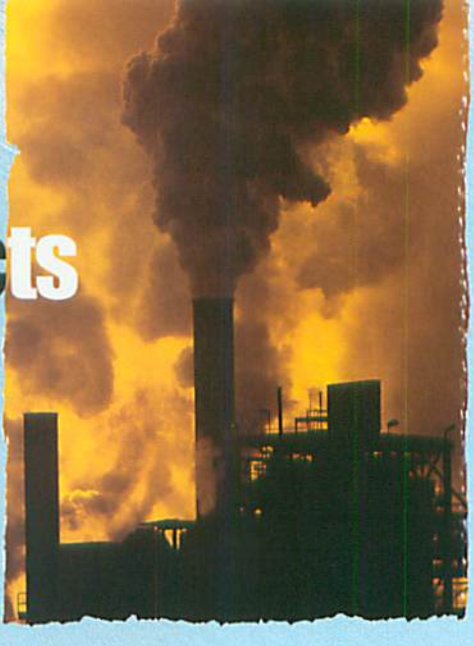
But now evidence is gathering that human activities are changing or perhaps accelerating climate change. The earth appears to be warming. Can we distinguish human effects on climate change from the background of natural change? More importantly, can we predict the rate and extent of future changes and their impacts on our lives?

Here we spell out what we know as facts about climate change and what can be predicted from those facts. We also want to make clear where there are uncertainties in both our knowledge and our predictions.

The information presented here is gathered from a wide range of published international sources and includes work done by scientists funded by the UK's Natural Environment Research Council, the Meteorological Office and the Department of the Environment, Transport and the Regions. The study of climate change is both an international and an interdisciplinary effort in which co-operation is essential if we are to understand the drivers and processes of climate change.

Natural Environment Research Council

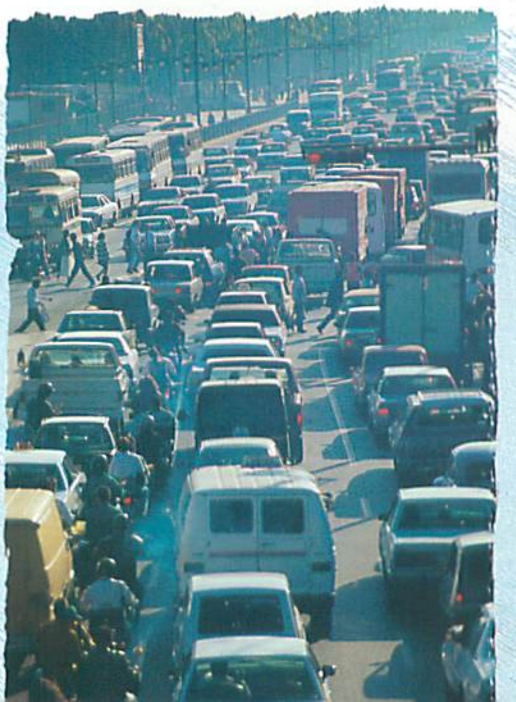
# Widely accepted facts



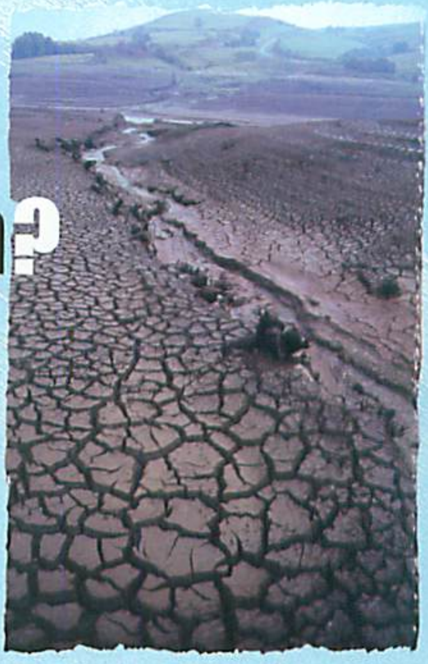
- Average global temperature has risen by 0.6°C in the last 130 years.
- Carbon dioxide levels in the atmosphere have risen by about 25% in the last 200 years, increasing from about 280 parts per million to 356 parts per million today.
- Methane levels in the atmosphere have doubled over the last 100 years.
- Nitrous oxide levels are rising at about 0.25% each year.
- Carbon dioxide, methane and nitrous oxide are all greenhouse gases which trap radiation emitted from the earth's surface, keeping the earth warmer than it otherwise would be.
- Carbon dioxide, methane and nitrous oxide levels are rising mainly as a result of human activities connected with energy generation, transport and agriculture.
- The order of importance in contributing to human-induced global warming is carbon dioxide (70%), methane (20%), nitrous oxide plus other gases (10%).
- Temperature has not increased as much as you would expect from the observed carbon dioxide increase. It is thought that tiny particles in the atmosphere from, for instance, industrial activities or volcanic eruptions, reflect sunlight and produce a cooling effect.
- A doubling of carbon dioxide levels would theoretically lead to an average global temperature rise of 1-2°C **if** all other factors remained the same. But in reality other factors will also change in response to rising temperature and may produce feedbacks, some negative, some positive. For example, water vapour in the atmosphere increases as temperature rises and is itself a potent greenhouse gas.

**Q** *How do you get from what we know now about rising carbon dioxide and temperature to future predictions, when we know that other factors such as increasing water vapour interfere?*

**A** *Complex computer models have been developed in several countries, including the UK, which help predict climate changes and their effects. These models represent the key processes in the atmosphere, oceans, ice and on the land and are in many ways similar to weather forecast models.*



# What is likely to happen?



## *global consequences*

If greenhouse gas emissions continue on a "business as usual" basis, models predict that carbon dioxide levels will double from pre-industrial levels by the end of the next century. When the effect of other factors such as increased water vapour is added, the estimated average global temperature rise will be between 1.5 and 4.5°C, the most likely value being 2.5°C.

The rise in temperature will produce an impact on a wide range of climate-related factors.

Global sea levels are likely to rise by about 50 cm over the next century, and will continue to rise further in the future. Low-lying coasts will flood and some habitats such as saltmarshes will be lost unless they can be protected from flooding.

We might expect more extreme weather events - heatwaves, floods, droughts, storms - but it is impossible to predict where these are likely to occur with the present generation of models.

The world's vegetation zones will undergo major changes, in particular boundary shifts between grasslands, forests and shrublands.

Deserts will become hotter, desertification will extend and is more likely to become irreversible.

Half the world's glaciers could melt and Arctic ice would be reduced in extent. When ice melts, the amount of solar radiation which can be absorbed by the exposed land increases so warming will be amplified further.

Freshwater systems will experience changes in temperature, flows and levels, affecting biodiversity, water supplies and probably water quality. Human conflict over access to water resources may increase.

Agricultural productivity is likely to vary across regions. Although global productivity may stay about the same, there may be increased risk of famine in arid and semi-arid regions.

Mass movements of people away from flooded or arid regions would cause conflicts and health problems.

Human and animal diseases may spread to new areas.

## *UK consequences*

The UK will be directly or indirectly affected by most of the expected global impacts of climate change. The specific effects will depend upon regional changes which are impossible to predict accurately at present. A general northwards shift by 50 - 80 km per decade of natural habitats and agricultural zones is likely. Forestry and some forms of farming are likely to benefit, but significant impacts are likely on soils, wildlife, water resources and agriculture in the south.

# Uncertainties

Most scientists agree that the climate is warming as the result of human activities, but uncertainties abound at almost all the stages of climate prediction. Some of these uncertainties are sufficient to lead a very few experts to doubt that warming is happening at all. Other experts query the extent to which the observed warming is unusual or how much of it can be attributed to human acitivities. Much of the current research effort is aimed at reducing the uncertainties.

## *uncertainties over the facts*

**Carbon budgets** Carbon moves between the atmosphere, where it occurs mainly as carbon dioxide, and all other parts of the environment - soil, vegetation, oceans, rocks and so on - forming the global carbon budget. We are not sure what determines how much carbon is in which part of the earth's systems and the rate at which it moves between the parts.

**Temperatures** fluctuate annually and over much longer timescales associated with the natural variability of the climate. Accurate records using instruments have only been made for about a century. Past records are inferred from other evidence. Identifying small warming trends against this background variation is difficult.

**Solar radiation** varies due to physical changes in the sun, the best known being the 11-year sun-spot cycle. Variations detected using satellites over the last 20 years are small, less than 1%. It is not clear whether variations over a long timescale might be more significant and what effect any of this variation has on the warming of the earth.

## *uncertainties over climate "feedbacks"*

Once climate change begins, many other factors we have been measuring or estimating also start to change. Some can increase the rate of change, others can produce feedbacks which slow things down. Some examples are:

**Clouds** Clouds can reflect incoming solar radiation back into space, keeping heat out. But clouds can also prevent radiation from the earth's surface escaping, thus keeping heat in. So the effects can be positive or negative depending on the height, temperature and reflecting properties of the clouds, all of which vary in time and from place to place. The effects of clouds are poorly understood and they remain one of the biggest uncertainties.

**Water vapour** A warmer atmosphere can hold more water vapour which is a powerful greenhouse gas, thus amplifying the warming by positive feedback.

**Plant growth** may increase if carbon dioxide rises, thus absorbing more carbon from the atmosphere - a negative feedback.

**Polar ice sheets** will melt to some extent as temperatures rise, but melting will be partially balanced by greater snowfall over polar areas. Arctic ice sheets will melt faster than snow will accumulate, therefore adding to sea level rises. But in the Antarctic, recent studies suggest that the interactions of ice shelves (the parts of the Antarctic Ice Sheet which extend out over the ocean) with the waters beneath are complex, and that warmer temperatures will not necessarily result in thinner ice sheets and shelves in the southern hemisphere.

**Reflectance** - changes in the distribution of vegetation in warmer climates may alter the reflectance and thus the capacity of the earth to absorb heat. Less snow cover over the continents of the northern hemisphere in warmer conditions will mean more solar radiation absorbed by the darker surface.

## *uncertainties over "flipping systems"*

Few of the systems in climate models are simple, as many of the factors listed above indicate. Doubled input does not necessarily lead to doubled output. One particular feature of complex systems is that under particular conditions, they may change abruptly and massively. Small incremental changes in one variable, such as the amount of a greenhouse gas, could trigger a switch response to a different state in one of the earth's systems.

One example may be "El Niño", a periodic event in the Pacific Ocean in which sea temperatures rise sharply on the eastern side and have a strong influence on the weather patterns throughout the world. It is not certain what sets off this sudden but quite natural change in ocean currents and movements of air. We also do not know how such events may change in a warmer world.

Another example may be the North Atlantic circulation system known as the "The Atlantic Conveyor Belt". This is a current system which carries warm surface water northwards and returns cold deep water to the south. It results in a transfer of free heat to the atmosphere equivalent to 30,000 times the power-generating capacity of the UK. This gives western Europe its present temperate climate. Disruptions to the system in the past have coincided with rapid transitions into and out of ice ages. Models show that disruptions could occur if more fresh water enters the Arctic Ocean as a result of global warming.

# Can we change the course of climate change?

Carbon dioxide has an effective lifetime in the atmosphere of about 100 years, so concentrations respond very slowly to changes in emissions. If we stabilise carbon dioxide emissions (as agreed by developed countries at the 1992 Summit in Rio de Janeiro) the rate of climate change will slow down. But we would need to reduce current carbon dioxide emissions by about 60% globally to prevent carbon dioxide concentrations from rising further.

# Contacts

**NERC Centre for Global Atmospheric Modelling**,
Department of Meteorology, University of Reading,
2 Earley Gate, Whiteknights, Reading RG6 2AU.
Tel: 0118 931 8315, fax: 0118 931 8316.
Website: http://www.met.rdg.ac.uk/ugamp/ugamp.html

**The UK Global Environmental Research** (GER) **Office**,
Polaris House, North Star Ave, Swindon SN2 1EU.
Tel: 01793 411734, fax: 01793 444513, email: ukgeroff@wpo.nerc.ac.uk
Website: http://www.nerc.ac.uk/ukgeroff/welcome.htm

**Hadley Centre for Climate Prediction and Research**,
Met. Office, London Road, Bracknell RG12 2SY.
Tel: 01344 856653, fax: 01344 854898, email: gjjenkins@meto.gov.uk
Website: http://www.meto.gov.uk/sec5/sec5pg1.html

**Global Atmosphere Division**, DETR, B252A Romney House,
43 Marsham Street, London SW1P 3PY.
Tel: 0171 276 8711, fax: 0171 276 8509, email: ga@globatmo.demon.ac.uk

**Intergovernmental Panel on Climate Change**,
the Secretariat c/o The World Meteorological Organisation,
Case postale 2300, CH-1211 Geneva 2, Switzerland.

**UK Environmental Change Network**, Central Coordination Unit,
ITE Merlewood Research Station, Grange over Sands, Cumbria LA11 6JU.
Tel: 015395 32264, fax: 015395 34705, email: t.parr@ite.ac.uk
Website: http://mwnta.nmw.ac.uk/ecn/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*For further information about NERC and its work, contact* ***NERC Planning and Communications Directorate***
*Tel: 01793 411623, fax: 01793 411510, email: nerccomm@wpo.nerc.ac.uk*
*Website: http://www.nerc.ac.uk*


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